Rubber Research Scheme (Ceylon).

Second Quarterly Circular

for

1929.

July, 1929.

H. W. CAVE & CO., PRINTERS.

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ON THE OCCURRENCE AND SIGNIFICANCE OF OIDIUM LEAF DISEASE IN CEYLON.

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REPORT ON EFFECT OF KEEPING COAGULUM IN SERUM ON THE PLASTICITY OF SMOKED SHEET.

IT was previously shown and confirmed that when coagulum is allowed to remain in the serum from 3 to 45 hours before rolling to crepe there is a progressive decrease in the plasticities of the rubber six months after preparation (Bulletin 49).

Two further series of experiments have now been completed in which the coagulum after keeping for various periods in the serum was converted into smoked sheet. In the first series the coagulant was acetic acid; in the second, acetic acid and paranitrophenol. It was considered that paranitrophenol might retard maturation and therefore reduce variations due to the period for which the coagulum was kept in the serum.

The samples were submitted to two sets of tests. In one, bulk samples were stored at 60°F and submitted to mastication tests at the end of six months. In the other, small pieces were stored for six months under various conditions and submitted to compression tests (without mastication) at the beginning and end of the period of storage.

Mastication tests.—The following are the results of mastication tests on the bulk samples stored for six months at 60°F:—

Sample No.	Coagulant.	Period coagulum kept in serum.	Number of grindings required to produce fixed rate of extrusion at 85°C.
		(hrs.)	
1385	Acetic acid	4½	94
1386	,, ,,	17¾	95
1387	,, ,,	35½	95
1388	,, ,,	40¼	120
1389	,, ,,	55½	109
1390	Acetic acid and	4½	104
1391	paranitrophenol	17¾	109
1392	,, ,,	35½	108
1393	,, ,,	40¼	105
1394	,, ,,	55½	107

Samples 1385 and 1387 required less mastication than samples 1388 and 1389 which were prepared from coagulum kept in the serum for longer periods. The results however are irregular and it is concluded that there is no marked indication that keeping the coagulum in the serum causes smoked sheet to

become less plastic, as was found previously for crepe. The samples containing paranitrophenol have given very uniform results similar to the average given by samples without paranitrophenol.

Compression tests.—Compression tests were carried out on samples before and after storage for six months (a) at 60°F, (b) at about 40°F, (c) at 60-70°F over water and over calcium chloride.

The following are the results of compression tests on the unmasticated rubber by the de Vries modification of the Ira Williams method after 30 minutes' compression, viz. D30 or thickness in $\frac{mm}{100}$ of 0·4 grams under load of 5 kgs at 100°C.

After storage for six months.

Sample No.	Coagulant	Period in serum.	Before storage.	40°F (a)	408F (b)	60°F	Over water at 60-70°F.	Over calcium chloride at 60-70°F.
1385	Acetic acid	4½	154	156	150	161	188	166
1386	,, ,,	17¾	158	151	155	158	197	175
1387	,, ,,	35½	156	154	166	165	199	185
1388	,, ,,	40¼	156	155	159	161	195	180
1389	,, ,,	55½	159	163	157	167	195	183
1390	Acetic acid	4½	151	163	160	156	200	181
1391	and para-	17¾	158	158	162	151	192	180
1392	nitrophenol	35½	155	160	162	158	210	184
1393	,, ,,	40¼	156	161	160	163	199	186
1394	,, ,,	55½	155	163	165	167	204	182

There was little difference in the hardness of the samples before storage.

Samples stored in air at 40°F or 60°F without definite control of the moisture conditions changed very little in hardness during the period of storage, but those stored in a very dry or wet atmosphere at 60-70°F have hardened considerably, the sample prepared from coagulum kept for the shortest period in the serum hardening the least. The samples stored under very dry or very wet conditions therefore have given results resembling those previously given by crepe.

The results show that the conditions of storage, particularly the moisture conditions, may have an important effect on the hardness of unmasticated rubber.

The residue of the bulk samples are now being stored at the Imperial Institute for a further period of six months under various conditions of temperature and moisture and also over oxygen and carbon dioxide.

Vulcanisation tests.—The following are the results of tests after vulcanisation for 100 minutes at 148°C in the rubber-sulphur mixing 90:10:—

Sample No.	Coagulant	Period coagulum left in serum.	Tensile Strength.	Elongation at load of 1:04 kgs./sq. mm.	Calculated time of vulcanisation.
		(hrs.)	(lb./sq. in.)	(per cent.)	(mins.)
1385	Acetic acid	4½	1580	853	120
1386	,, ,,	17¾	1670	848	118
1387	,, ,,	35½	1850	832	114
1388	,, ,,	40¾	1840	840	116
1389	,, ,,	55½	1850	820	111
1390	Acetic acid	4½	1460	860	121
1391	and para-	17¾	1950	840	116
1392	nitrophenol	35½	1560	847	118
1393	,, ,,	40¾	1830	824	112
1934	,, ,,	55½	1950	824	112

There is a small progressive decrease in the time of vulcanisation with the period the coagulum was allowed to remain in the serum. This is possibly due to maturation or to the retention of extra serum substances.

The tensile strengths of the samples are on the whole satisfactory.

The samples containing paranitrophenol behave similarly to the control samples coagulated with acetic acid alone. There is no evidence from these experiments therefore that parnitrophenol is likely to reduce variation. This is not a conclusive experiment on this point, however, as maturation may not be the cause of the small differences observed in time of vulcanisation.

Imperial Institute,

London, S.W. 7.,

February, 1929.

N.B.—It is proposed to repeat these tests.

NOTE ON BROWN BAST TREATMENT.

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IN connection with the treatment of brown bast advised in Rubber Research Scheme Bulletin No. 48 the question has naturally arisen whether the renewed bark was likely to be more readily affected by brown bast than normal bark. The writer has on several occasions expressed the view that such bark was probably no more susceptible to the disease than normal bark, but owing to the short space of time during which the treatment has been practised in Ceylon it was not possible to make a positive statement.

Recent evidence has, however, been obtained which suggests that this view is probably correct. The treated tree shown in Plate VII of Rubber Research Scheme Bulletin No. 48 has now been tapped for over two years on the third-day system and is continuing to give satisfactory yields and there are no indications of brown bast development.

The present photograph of this tree was taken after slight rain had fallen hence the overflow of latex on parts of the cut but it will be noted that the flow is normal. The superintendent of the estate on which this photograph was taken informs me that many other trees scraped in 1927 are being successfully tapped and that he anticipates that over one thousand treated trees will be in bearing during 1930.

Treated tree which has been tapped for two years since the renewal of the scraped surface.

AN INDIRECT METHOD OF MEASURING THE AMOUNT OF FOLIAGE ON DIFFERENT BLOCKS OF TREES.

R. A. TAYLOR, B. Sc.,
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THE method to be described has been carried out successfully in estimating the effects of various manures on the foliage cover in rubber and can be used to obtain a measure of the effect produced by spraying or manuring against leaf diseases of rubber.

The amount of shade under the trees is estimated by comparing the depth of tint obtained when pieces of photographic daylight printing paper are exposed for known lengths of time, the depth of tint being inversely proportional to the amount of shade and consequently to the density of the foliage cover.

It is essential that the light should be uniform throughout the period of measurement and that the sun should be overhead. The observations should, therefore, be made between 11.30 a.m. and 12·30 p.m. on a bright cloudless day. To obtain a proper estimate of the average depth of shade the observer should, while making the exposures, keep moving at as uniform a pace as possible through each plot as there are always patches of bright light and dense shade in the plots.

To minimise the effect of possible variations in the different sheets in each package of printing paper it is advisable to make one exposure in each block on the same sheet. To enable this to be done a printing frame 12 ins. by 10 ins. fitted with a sheet of plain glass is used. A well-fitting wooden screen is supplied for this frame and held in position by four catches. In this screen a number of circular holes one inch in diameter are bored and are closed by rubber bath plugs. The printing paper is inserted behind the glass in the usual way.

When an exposure is to be made the plug bearing the number or letter of the block of trees to be tested is removed and the arranged time of exposure measured by a stop watch. The plug is replaced immediately on expiry of the period. Well-fitting plugs are essential for success. When all exposures have been made the printing paper can be fixed in the same way as an ordinary photographic print and a permanent record is obtained.

With Ilford P.O.P. mauve, one minute exposures have been found to be suitable and the following procedure for fixing is recommended:—

Wash in running water	5 minutes
Fix in 15% hypo	10 ,,
Wash in running water	2 hours.

To obtain a numerical value for the depth of tint a series of standards has to be prepared. On the frame used by the writer there were 25 holes allowing 25 exposures to be made without the necessity of changing the paper. The frame was laid flat on open ground at 12 noon and one plug removed every two seconds. When the last exposure had been made the frame was covered and taken to the laboratory and the exposed printing paper fixed by the method described above. The tints on this standard sheet were numbered 2-4-6-8, etc., and were used for comparing the tints obtained by exposures made under the trees. It was found that the tints obtained by exposure to direct sunlight were not exactly the same as those obtained under partial shade. For this reason it is preferable to prepare the standard in ordinary light which should be of uniform and constant intensity during the period of the exposure. Periods of longer duration than two seconds should then be employed. The values obtained have no absolute meaning but provided the exposures are carefully made the results obtained would in the writer's opinion be capable of statistical examination.

Fig. 1. shows the printing frame and the perforated screen with the plugs.

Fig. 2A. shows a sample result obtained on 25 blocks of trees and Fig. 2B. a standard sheet for comparison.

Research Laboratories,
Culloden Estate,
Neboda, 10-2-29.

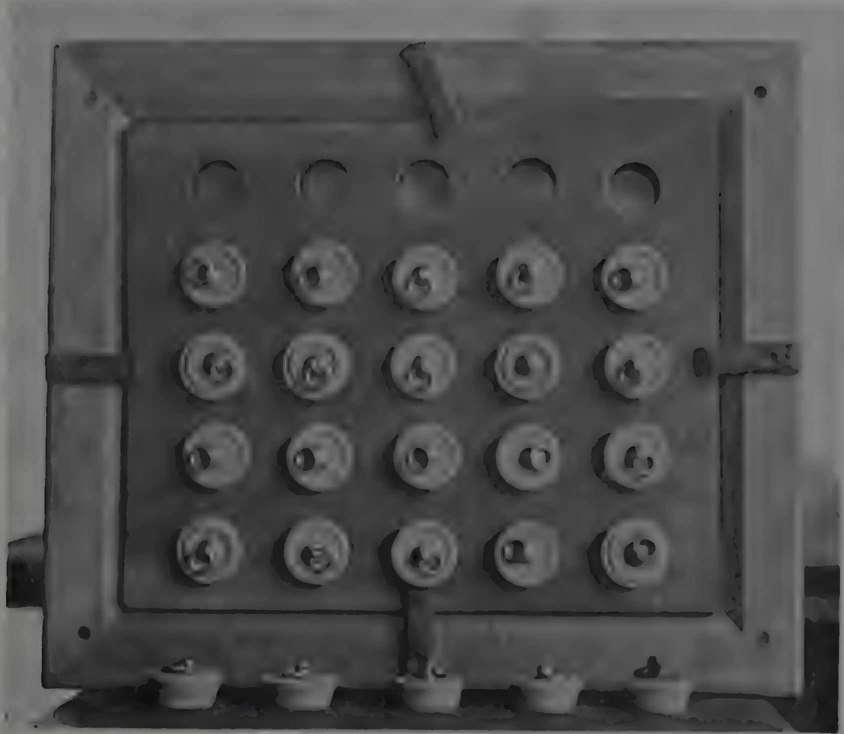

Fig. 1.

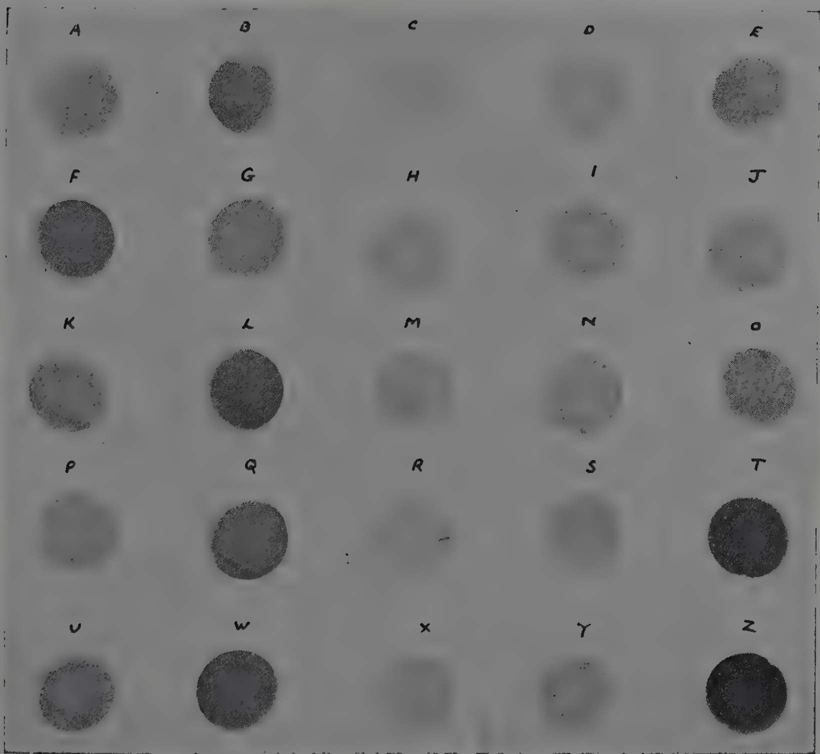

Fig. 2 A.

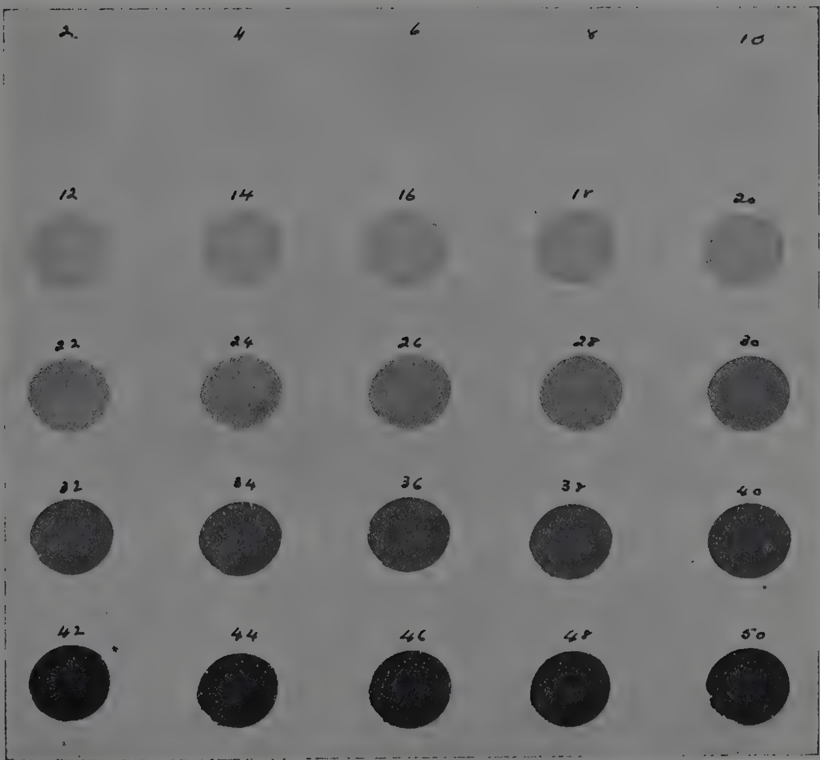

Fig. 2 B.

ON THE OCCURRENCE AND SIGNIFICANCE OF OIDIUM LEAF DISEASE IN CEYLON.

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1. *Introductory*.—In view of the attention which planters in Ceylon are now giving to *Oidium* leaf disease of Hevea and the concern with which it is justifiably regarded by reason of its rapid spread and increase in severity in this country and its bad record in Java, it is thought that a discussion of the disease as it affects the Ceylon planter and a consideration of possible methods of control is not inopportune. Much of the information regarding the occurrence and distribution of *Oidium* in this island is the outcome of a questionnaire circulated in 1928 and 1929 to all estates subscribing to the Rubber Research Scheme, and the writer would like to express his gratitude to the superintendents of these estates for their valuable assistance without which such an enquiry would have been impossible. The opportunity is also taken of summarising the available information regarding the morphology of the fungus and the symptoms and significance of the disease.

2. *Historical*.—The disease was first reported in Ceylon in 1925. In February of that year, when the trees were refoliating after wintering, an abnormal leaf-fall was reported almost simultaneously from most of the rubber-growing districts in the island, and specimens sent to the Department of Agriculture were identified by the Mycologist as similar to the *Oidium* leaf disease of Hevea which had been known in Java since 1918. The outbreak of the disease coincided with unusually heavy rains during February and March, and both Gadd (4) and Stoughton-Harris (10) concluded that this abnormal rainfall had favoured the development and spread of the disease and predicted that, in future years under the dry climatic conditions which normally obtain when the trees are refoliating, the disease would not recur to any serious extent. This prediction has unfortunately not been fulfilled, and, although the heavy rainfall in February and March 1925 may possibly have helped the fungus to adapt itself to its new host, there is now abundant evidence to show that the activity of the fungus is not dependent on unusually wet

conditions. Since 1925 the disease has become more widespread each successive year (with the exception of 1926 when there was a check in the spread of the disease) and in some districts, notably at mid-country elevations, it has rapidly increased in severity.

In the Dutch East Indies the disease was first reported by Arens (1) in 1918, and, whilst varying in intensity in subsequent years, it has in general increased greatly in severity and is now regarded by planters in Java with the utmost concern.

Oidium has not been reported on Hevea in Malaya, though in 1925 Sharples (8) reported a disease whose symptoms were almost identical with those of the *Oidium* leaf disease of Ceylon and Java. The fungus causing this disease was apparently *Gloesporium alborubrum*, a fungus differing in many respects from *Oidium*.

Oidium has also occurred in Uganda where it was first reported in 1921. In 1925 the Government Mycologist reported that the disease had become more severe and was probably responsible for considerable decreases in yield.

3. *Symptoms and Effects*.—The symptoms of *Oidium* leaf disease have been described by several observers in Ceylon and Java and are sumarised as follows:—

Oidium can attack Hevea leaves of all ages and the effects of the attack differ according to the degree of maturity of the leaf. The disease is first evident as an attack on young leaflets when the trees are refoliating after wintering. If the leaves are attacked when still bronze-coloured and shiny they become dull and faded in patches and may become slightly crinkled. The leaflets may fall in this condition or the tip may first die back, becoming bluish-black in colour. The symptoms are very similar when the attack is on slightly older leaves which have just turned green, except that in such cases the curling and crinkling is usually more pronounced. The white powdery superficial growth of the fungus consisting of mycelium and spores is sometimes clearly seen on the petiole and under surface of the mid-ribs of such young leaves, but more often it is only visible with a lens. The fallen leaflets soon shrivel on the ground, but in the case of a severely attacked tree they often form a conspicuous carpet of leaves. All three leaflets of any one leaf do not necessarily fall, so that a characteristic feature of diseased trees is the presence of petioles bearing one or two leaflets instead of three. Trees which are severely defoliated in this way usually put out a fresh crop of leaves and so recover. These secondary leaves may, however, be attacked in turn.

If the fungus attacks somewhat older but still immature leaves the effect is rather different. Such leaves are more resistant and the attack is confined to localised portions of the margin and mid-rib. These are prevented from growing normally with the consequence that the leaflet becomes irregularly distorted into folds and crinkles. Severely attacked leaves are dull and yellowish. The leaflets do not usually fall so that this form of attack is not as serious as that on the very young leaves when complete defoliation of the tree may result. The attack on immature leaves is for convenience known as primary attack and occurs soon after wintering.

Oidium may also attack fully mature leaves, such an attack being turned secondary. The first symptoms of a secondary attack is the appearance of small yellowish translucent spots chiefly on the upper surface of the leaflet. The fine superficial hyphae of the fungus can be detected on these spots with a lens, and the subsequent production of spores gives the spots a white powdery appearance. As the spots grow larger they turn purple-brown in colour and eventually dry up, while the dead tissues in the centre may fall out leaving irregular holes. No hard and fast distinction can be drawn between this secondary form of attack and that previously described on the older but yet immature leaves; in fact a characteristic symptom of the disease is the existence of distorted leaflets with the mottled appearance of the secondary attack.

Oidium also attacks and destroys the flowers, and the young inflorescences are often thickly covered with a growth of mycelium and spores. In a badly-affected area the complete absence of seed is a characteristic feature of the disease.

While the above description is in general applicable to the disease as it occurs in any part of Ceylon, there are certain differences between the symptoms and effects of the disease in a comparatively dry district such as Matale and those in a wet district such as Kalutara. (These two districts are mentioned as having come under the special observation of the writer.) Although the differences are only in degree they are sufficiently striking to be worthy of record. One of the most notable features of the disease in Matale is the abundant superficial growth of mycelium and spores on the surfaces of the leaves whereas in the Kalutara district it is comparatively rare to find an affected leaf on which the fungus is visible to the naked eye. In Matale most of the diseased leaves, whether the attack is primary or secondary, exhibit the superficial powdery growth which gives the name mildew to this class of fungus. Indeed, the leaves are sometimes so white as to appear to have been splashed with whitewash. This difference is not entirely due to the fact that the disease is

far more severe in Matale than in Kalutara, but is probably related to the different atmospheric conditions. In Matale, even where the annual rainfall is high, the average humidity of the atmosphere is lower than in Kalutara, and this comparatively dry atmosphere is favourable to the production of spores. The relation of weather conditions to the disease is further discussed below under the heading of *Occurrence, Distribution, Environmental Factors.*

In the low-country, where *Oidium* is not so severe as in certain districts at higher elevations, the disease usually appears in February or March, is active for a few weeks, and then disappears as suddenly as it came. Hence a defoliated tree which puts out a second crop of leaves is rarely attacked a second time and so recovers at the cost of food reserves. In severely attacked areas, on the other hand, although the disease exhibits a period of maximum intensity shortly after the normal wintering, the fungus may remain active throughout the year. In this way many trees are subject to a continuous process of leaf-fall and refoliation, the leaves becoming smaller and poorer in quality at each successive recovery. On an estate in Matale which has come under the writer's observation the rubber is affected in this way, and the worst affected trees artificially winter five or six times a year.

Such a continual defoliation no doubt results in a depletion of food reserves and general lowering of the vitality of the tree. In consequence a physiological die-back of twigs is a characteristic feature of badly-attacked areas. Such dead or dying twigs are liable to afford entry for *Diplodia* which may kill the branch or even the whole tree.

4. *The Fungus.*—The disease is caused by *Oidium heveae*, a fungus belonging to the class of powdery mildews. The mycelium, which consists of colourless, septate, branched hyphae, lives on the surface of the affected part and draws the necessary food by sending sucking organs known as haustoria into the tissues of the host. Under favourable conditions the mycelium produces erect conidiophores up to 46 microns in length (1 micron =1/1000 mm.) at the end of which are abstracted the conidia (spores). These conidia are usually borne singly but may occur in chains up to five. They are hyaline, barrel-shaped, constricted near the ends and thin-walled. Various observers give different figures for the size of the spores, but Stoughton-Harris (10) in Ceylon and Arens (1) and Steinmann (9) in Java agree in giving the measurements as 28-42 microns long by 14-23 microns broad. The production of the spores on the surface of the rubber leaves and flowers gives the typical powdery appearance. The spores are readily carried away by the wind and are

capable of immediate germination on reaching a suitable host. Many powdery mildews have been shown to have an ascospore stage of the family *Erysiphacoae*, but the Hevea mildew, like most tropical mildews, is only known in the conidial stage. Thus it is probable that the conidia provide the only means by which the fungus is capable of spreading.

For some time it was not known how the fungus wintered, *i.e.*, carried over the period when the disease is not active. Bally (2) in 1927 advanced three hypotheses: (1) That perithecia and ascospores may be produced; these would provide material for infecting the young leaves after wintering; (2) That *O. heveae* may comprise biological strains capable of parasitising other hosts; (3) That the mycelium may overwinter in the leaves or branches of the rubber trees. No evidence to support the first two hypotheses has been forthcoming; an ascospore stage has not been found, while none of the infection experiments with mildews occurring on other members of the *Euphorbiaceae* have given positive results. The third hypothesis has been proved to be correct by the recent researches of Bobilioff (3) in Java. He states that the fungus hibernates on the few young shoots which are always produced by some trees throughout the year and on the infected spots of mature leaves. In an affected field there are at any given time a few trees whose young shoots are infected, and these are the sources of infection when the conditions are suitable for an outbreak of the disease. The fungus remains active for about five weeks after which there is a decrease of the mycelium and dying of the conidia. In the main, observations on the life-history of the fungus in Ceylon confirm Bobilioff's statements, except that in badly-affected areas in certain districts the fungus never becomes wholly inactive so that the disease is present at all times of the year.

5. *Occurrence, Distribution, Environmental Factors.*—A list of questions regarding *Oidium* was circulated to all estates subscribing to the Rubber Research Scheme in June 1928 and again in May 1929. The estates from which replies were received were divided into four classes according to the severity of the attack, and the number of estates in each class for the year 1929 is as follows:—

Severe attack	17
Infection general but not severe	55
Very mild attack (a few isolated trees)	65
No Oidium	41
Total no. of estates	178

Of a total of 178 estates 137, or 77%, have suffered in greater or less degree from *Oidium*. In 1928, of 233 estates from which replies were received, 55% reported the occurrence of mildew so that a spread in the occurrence of the disease during the last year is to be noted.

Each individual estate has been marked on the enclosed rough map, the shading corresponding to the degree of *Oidium* attack. The classification of the estates is of doubtful accuracy since every superintendent does not judge the severity of the attack on his estate by the same standard. The value of the map is also limited by the comparatively small number of estates shown. It is considered, however, that the general distribution of the disease is accurately indicated. The map shows clearly that the Matale and Uva districts are the most severely affected, while Ratnapura remains almost free from the disease. In the Kalutara and Kelani Valley districts *Oidium* is widespread but has not yet caused much damage.

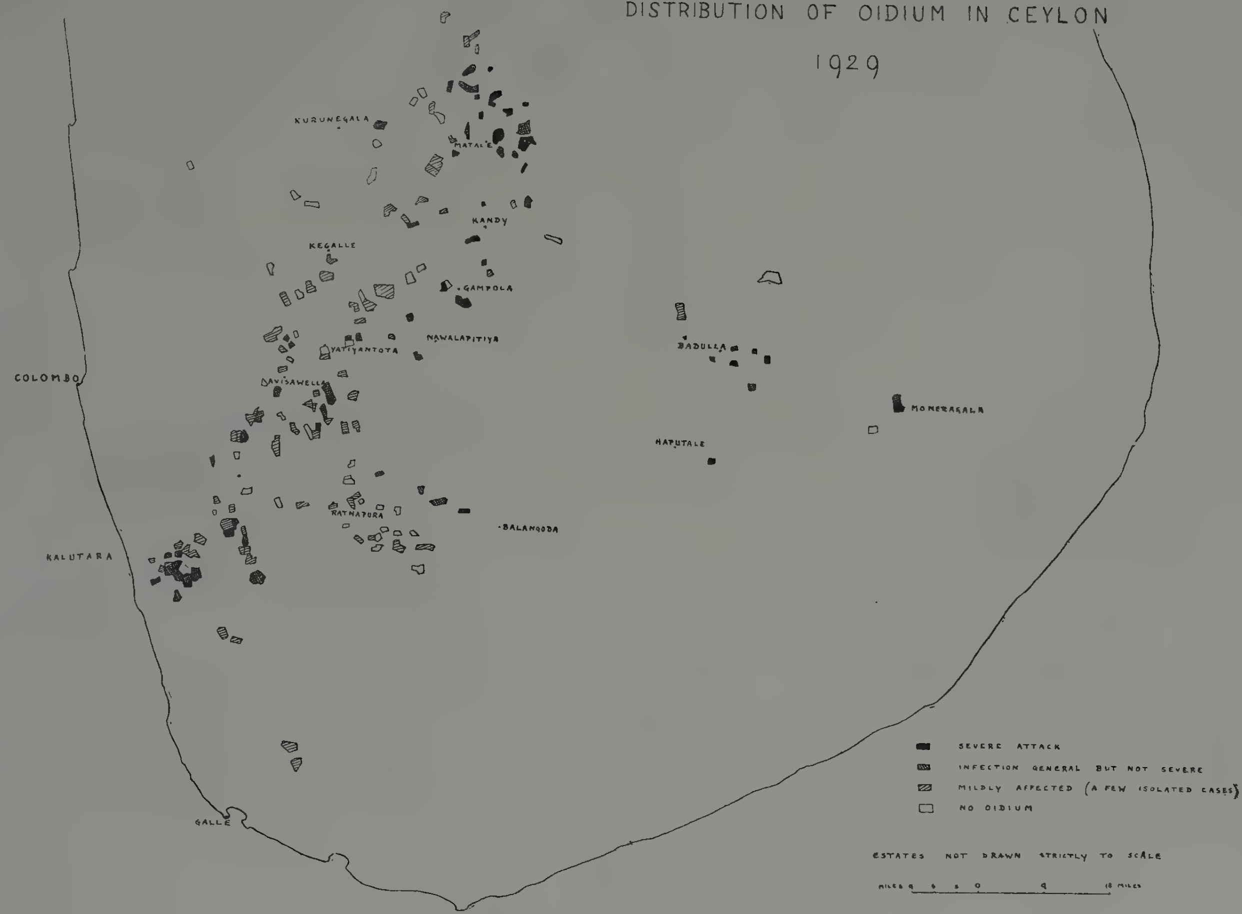
In an attempt to correlate the distribution of *Oidium* in Ceylon with environmental conditions certain general conclusions may be formed. The disease has become severe only at the higher elevations at which rubber is grown in the island, and on no estate below 1,000 ft. above sea level has *Oidium* caused the degree of defoliation that has occurred on certain mid-country estates. The greater severity at higher elevations is probably due in part to the poorer growth of the rubber in consequence of which the trees are less able to withstand an attack, and in part to the fact that the weather conditions in such districts are more favourable to the development and spread of the fungus.

The relation of weather conditions to *Oidium* attack is a problem of considerable complexity. It is not possible to deduce a definite correlation between rainfall at any particular time and intensity of the attack as can be done with certain other diseases. Diseases caused by powdery mildews are regarded as dry-weather diseases, and it is of interest to note that in Java the more severe attacks have been associated with unusually dry-weather conditions. Reydon (6), as the result of an enquiry in East Java in 1927, found that the rainfall on estates severely attacked by mildew was in nearly every case less than that on neighbouring estates where the attack was mild. He states, however, that "to conclude herefrom that more rain means less mildew is, in our opinion, rash, because we do not know exactly the nature of the influence of the rain on mildew attacks, and we must first find out when the young leaf period falls. The mildew attack is indeed, in the first place, dependent on this last factor."

In order to obtain information regarding the relation between intensity of *Oidium* attack and weather conditions in Ceylon the

DISTRIBUTION OF OIDIUM IN CEYLON

1929



following question was included in the questionnaire referred to above:—"Have you noticed that certain weather conditions lead to the more severe attacks ? If so, what ?" The answers to this question are very contradictory. The majority of superintendents maintain that wet weather while the trees are refoliating after wintering favours the disease. A close analysis, however, shows that most of these estates have only been mildly attacked, while of those estates which have experienced a severe attack the majority report that dry weather is a predisposing factor. A few estates report that they have had a severe attack in two different years, the weather conditions being abnormally wet in one year and abnormally dry in the other, while others consider that alternating dry and wet conditions are favourable to the disease. Many superintendents mention wind as conducive to severe attacks, and some associate an outbreak of the disease with cool, dewy mornings.

In the face of such varied opinions it will be of value to consider in what respects weather conditions may influence the stages in the life-history of the fungus. A certain amount of moisture is necessary for the germination of the spores and the vegetative growth of the mycelium. Dry conditions are favourable to the production of spores, while their dissemination is aided by wind. It is probable therefore that alternating dry and wet conditions during refoliation are favourable to the development and spread of the fungus. It is considered that a relatively dry atmosphere is the most important predisposing factor in the production of spores, and this is tentatively suggested as the chief cause of the severity of the disease in the Matale and Uva districts where the humidity of the atmosphere between falls of rain is lower than in the wet low-country districts. It has already been mentioned above that the production of spores is far more prolific at the higher elevations than in the low-country. It is not considered that heavy falls of rain are necessary for the germination of the spores and mycelial development and it is probable that dew provides sufficient moisture. A sharp storm, however, will often precipitate the fall of many leaflets and therefore appear to bring about a severe defoliation.

An outbreak of activity of the fungus is probably more dependent on the condition of the trees as regards new leaf than on any specific weather conditions. Any trees in an affected area which produce their new foliage when the fungus is active will be attacked. There is no evidence at the present time of any individual immunity or resistance to the disease except in so far that those trees which winter very early and very late may escape. Trees growing on poor washed-out soil and exposed ridges generally suffer more severely than those in the richer hollows. This is more probably due to their poorer growth, in consequence

of which they are less able to recuperate from the effects of the disease, than to any greater susceptibility. The disease is often first noticed on exposed hill slopes which is probably due to the fact that such areas usually winter earlier than the lower-lying ground with richer soil. On any estate on which rubber is grown at different elevations the disease is nearly always more severe at the higher elevations.

An examination of the map will show that estates isolated by some miles from the nearest rubber are in general free from the disease. A study of the development of *Oidium* on individual estates shows that usually in the first year of appearance the disease is very mild and only affects a few isolated trees. These do not usually occur in definite groups but are scattered throughout the fields. In the second year the disease has usually become more widespread and may or may not cause severe defoliation. The history of the disease in subsequent years depends on the district and the climatic conditions, but it is rare for the disease, once having attained severe proportions, to decrease in intensity.

6. *Economic Significance*.—The economic importance of *Oidium* leaf disease is very difficult to estimate. Its importance, like any other disease of Hevea, must ultimately be judged by the loss in yield entailed, and there is at present a complete absence of exact knowledge on this point. In Ceylon no decrease in yield due to the disease has been reported from any estate. In East Java, as the result of an enquiry carried out by Reydon (6) in 1927, 6.4% of the estates reported a decrease in yield. It is not known, however, whether any of these estates have figures which would bear scientific scrutiny. In Uganda the Government Mycologist's Report for 1925 stated that the disease was probably responsible for a considerable reduction in yields, but here again no accurate figures appear to be available.

The absence of accurate knowledge as to the economic importance of the disease makes an estimation of the value of costly control measures impossible. Particular interest is therefore attached to experiments being conducted by the Rubber Research Scheme on an estate in the Matale district which are designed to show whether any decreases in yield occur as the result of severe attacks for several years, and whether spraying or manuring provide an effective and economic method of controlling the disease.

Although no decreases in yield have yet been reported in Ceylon, there can be little doubt that the cumulative effects of constant defoliation will lower the vitality of the tree and eventually cause it to yield less latex. The die-back of branches which occurs on badly affected estates is an indication of the depletion of food reserves, and is itself liable to result in decreases in yield per acre if the die-back extends and kills the whole tree.

Experiments carried out by Taylor (7) show that whereas at normal leaf-fall a large proportion of the nitrogen-containing substances are first withdrawn into the stem, when leaves fall as the result of attack by *Phytophthora* most if not all of the nitrogen contained in the leaf is lost. It is reasonable to conclude that the same is true for leaf-fall due to *Oidium* or any other fungus attack, and it is clear therefore that a considerable loss of valuable foodstuffs is entailed. The following extract from Taylor's paper is pertinent:—

"The loss of foodstuffs incidental to leaf-fall is, however, only a small part of the strain to which the tree is subjected. The whole manufacturing portion of the plant is affected and while the tree is leafless it is, so to speak, living on capital. What reserves are available must be encroached upon for the production of the new foliage as well as for the normal 'running expenses' such as production of latex, renewal of bark, etc., and this, unlike the normal wintering, occurs when the tree has made no special preparation."

The following figures show that the defoliation caused by *Oidium* can be far more severe than any effects that *Phytophthora* has yet produced in Ceylon. The figures are derived from the careful examination of 1,058 trees taken at random from two fields on an estate in the Matale district and the classification of their foliage as regards *Oidium* attack into six divisions. The examination of the trees was made in April when all but an insignificant proportion of the trees had undergone normal wintering and refoliation.

	No attack	Mild to moderate Secondary.	Severe secondary. Little or no defoliation.	Moderate defoliation.	Severe defoliation.	Complete or almost complete defoliation (partly recovered).	Total
No. of trees.	0	72	246	210	222	308	1058
Percentage of whole.		7%	23%	20%	21%	29%	

In the fields from which these figures were obtained no apparent decrease in yield had resulted as a consequence of three consecutive years' severe attacks, but it is impossible not to view with the utmost concern a disease which causes a complete defoliation of nearly a third of the trees and from which no single tree is altogether free. At present *Oidium* only has this sinister aspect

in certain areas at mid-country elevations which form a small proportion of the total rubber-growing acreage in Ceylon. In the low-country no effects comparable with the above have yet been reported, but there are indications that the disease is becoming more widespread every year, and it is possible that in the future it may become the serious menace which it is considered to be in Java.

7. *Control.*—In the control of a fungus disease there are always three possible lines of work: (a) Indirect control by cultivation methods; (b) Breeding immune or resistant varieties; (c) Direct control by eliminating the causative fungus.

As far as *Oidium* leaf disease of Hevea is concerned very little has yet been achieved along any of these three lines, so that this section must consist chiefly of a discussion of the possibilities of control.

(a) *Indirect control by cultivation methods.*—It is a well established fact that the application of nitrogenous manures benefits the foliage of rubber, and there is evidence to show that trees manured in this way, while no less susceptible to attack by *Oidium*, are bettter able to recover from the effects of the disease.

It may now be considered in what respects the application of manures will tend to be beneficial. Quick-acting nitrogenous manures actually increase the quantity of foliage initially put out by the trees after wintering, so that the effects of a partial defoliation will be less severe. It is also possible that manuring will hasten the leaf production and so lessen the period of susceptibility, but on the other hand the tree may be stimulated to such activity that it may be defoliated twice during the period of virulent attack. There can be little doubt that nitrogenous manuring will be of value in assisting the tree to put out a second crop of leaves after being defoliated and to make up for the drain on the resources of the tree thereby entailed. This is probably the most important respect in which manuring can be of value in the control of the disease, and any cultivation methods such as forking, growth of green manures, etc., which lead to a more vigorous growth of the tree will similarly be beneficial.

It is possible that direct control of the disease might be obtained by manurial methods if in this way the leaf could be rendered more resistant to invasion by the fungus either by thickening the cuticle or by altering the acidity of the cell sap to a value unsuitable to the growth of the fungus. No work on these lines has yet been done with Hevea, but results obtained with other crops indicate that such investigations might be of value. Potash is known to bring about a thickening of the cuticle of the leaves of some plants, and the possibility of this effect on Hevea is being investigated by the Rubber Research Scheme.

The writer's observations tend to show that heavy nitrogeneous manuring is of value on badly-affected estates, and reports from various estates are confirmatory. Of the answers to the questionnaires circulated in 1928 and 1929 a number of estate superintendents report that a definite benefit has resulted from the application of manures, while a much smaller number have replied that no benefit is to be noted. A few estates also report that the effects of *Oidium* are less severe on fields with a good cover of Vigna, though no such relation has been observed by the writer. The information available is far from being conclusive, however, and it is not possible at the present time to say with any degree of confidence whether manuring will provide an effective and economic method of controlling the disease. It is hoped that this lack of accurate knowledge will be remedied as the result of comprehensive field experiments at present being conducted by the Rubber Research Scheme.

(b) *Breeding immune or resistant varieties.*—No work on these lines has yet been undertaken in Ceylon. Should any tree be found which is resistant to the disease, not because it winters at a time when the fungus is inactive but because of some inherent property, it would form a valuable stock for planting in badly-affected areas, provided that it was a desirable tree in other respects. At the present time there is no evidence of immune or highly resistant individual trees, but a number of mildly attacked trees in a severely-affected estate have been marked and recorded and wll be specially observed during the next period of virulent *Oidium* attack.

In Java Bobilioff (3) has budded three different species of Hevea, *H.collina H.guyanensis*, *H.spruceana* high up on stocks of *H.brasiliensis*. These buddings have been planted out on two estates heavily infected with *Oidium*. It is hoped that the foliage of these species will be resistant to *Oidium*, the tapping surface, of course, being that of *H.brasiliensis*.

(c) *Direct control by eliminating the causative fungus.*—Since *Oidium* passes its entire life-history on the leaves and young shoots of the rubber tree any method of eliminating the fungus must be directed either towards killing the fungus *in situ* by the application of a fungicide or removing the branches which are the sources of infection.

The latter method has recently been tried in Java by Bobilioff (3). It has been mentioned above that the fungus hibernates on young shoots, and Bobilioff found that by removing these shoots before the wintering period the spread of the fungus to the young leaves was to some extent controlled. He concludes that such a cleaning process is a practical possibility and costs little. So far as the writer is aware this method has not been tried in Ceylon.

A fungicide can be applied either in the form of a wet spray, or a dry dust. In either case the chief problem with Hevea is the practical difficulty of making the application at a reasonable cost.

8. *Spraying.*—For effective control of a fungus disease by spraying three conditions must be satisfied. First, the fungicide used must be highly toxic to the organism; secondly, the spraying technique must be such that all affected surfaces are adequately covered, and, thirdly, the spraying must be done at the right time in relation to the life-history of the fungus and of the host.

The first of these provisions should be easily satisfied. Experience with diseases caused by powdery mildews on other crops has shown that sulphur, in one form or another, is the most effective fungicidal agent and the experiments of Gandrup and S'Jacob (5) indicate that the *Oidium* of rubber provides no exception to this rule. They have shown that whereas Bordeaux and Burgundy mixtures are of little value, Sulfinette, which is a proprietary lime-sulphur solution, is highly toxic to the fungus and kills not only by contact but also by virtue of the evolution of poisonous gases. They also found that a suspension of sulphur powder in water gave good results.

The following table is taken from Gandrup and S'Jacob's paper (5). All the trees in the sprayed and control areas were examined seven weeks after the spraying operations and were classified according to the degree of infection.

Fungicide used.	1. Not or only scarcely injured by mildew.		2. More injured than No. 1.		3. More injured than No. 2. (trees with a poor crown).		4. Totally leafless (partly recovered).	
	No. of trees	%	No. of trees.	%	No. of trees.	%	No. of trees.	%
Bordeaux Mixture.	69	18	64	17	49	13·5	200	52·5
Burgundy Mixture.	70	18	70	18	52	13	209	52·5
Sulfinette	97	25	112	29	38	9	134	36
Unsprayed.	65	16	57	15	67	14.5	205	54

The evidence regarding Sulfinette is not, however, conclusive. Bobilioff (3) states that in his experiments spraying with Sulfinette gave no success, and concludes that only when a spray highly effective against mildew has been discovered will spraying be an effective control method.

The writer has carried out laboratory experiments with Sulfinette which tend to confirm Gandrup and S' Jacob's results; they show that Sulfinette at ½ % concentration is highly toxic to

Oidium on contact and also has a vaporous action. It was concluded, however, that this vaporous action was very limited in scope, and, although to some extent it obviates the necessity for a complete covering of the leaves, this property does not lessen the necessity for a careful spraying technique. About 25 acres severely affected with *Oidium* were sprayed with Sulfinette in March and April 1929, but it is not possible at present to draw any reliable conclusions regarding the efficacy of this fungicide in the field. Further spraying experiments are to be undertaken as the result of which it is hoped that the most satisfactory spraying fluid may be discovered.

The success of spraying as a control measure against *Oidium* is, however, dependent not only on the toxicity of the fungicide but also on the effectiveness of the spraying technique. The latter aspect is relatively of far more importance in spraying the large Hevea tree than in spraying other smaller trees, and there is no doubt that the limiting factor in the spraying of rubber in Ceylon is the practical difficulty in making the application. With the spraying machines at present at our disposal it is not possible to project the fungicide to the top of a mature tree from the ground and climbing must therefore be resorted to. This adds considerably to the expense of the operation and makes it a slow and troublesome proceeding. If a machine could be devised sufficiently powerful to project a fairly fine spray to the top of the trees without any climbing being necessary, and at the same time not too cumbersome to be easily carried short distances by about six coolies, spraying would be a cheaper and quicker operation.

Various factors militate against the economic practicability of spraying rubber. One of the most important of these is the availability of water. This has to be carried by coolies, and the cost of spraying is therefore dependent to a large extent on the distance from the nearest water supply. On this account alone spraying would be an impracticable procedure on many estates which are poorly supplied with streams.

Another important limitation of the method is the slowness of the operation. A pump with two outlets can only spray 1-1½ acres per day, so that, in order to spray a large acreage in the limited time during which the maximum benefit can be expected to accrue, several machines and spraying gangs must be employed. A large proportion of the time is spent in climbing the trees, raising and lowering the pipe, and carrying ladders from tree to tree, and it is considered that, until a machine is devised which will spray the trees from the ground, the operation is bound to be slow and the cost high.

The optimum time for spraying against *Oidium* is not at present known. The fungus is present on the foliage throughout the year, being most active for a period of a few weeks while the trees are refoliating after the winter. It will probably be of little value to spray during the active period since the leaves, which are then growing, will not remain adequately covered. It seems probable that the best control will be obtained by spraying shortly before the trees winter; in this way the fungus will be killed while inactive on the old leaves and green twigs, and the source of infection of the young foliage will thereby be destroyed. Satisfactory spraying can only be done in dry weather, and in view of the epiphytic habit of the fungus it is possible that some measure of control may be obtained at any time of the year provided that the weather conditions are suitable. It is hoped that experiments being conducted by the Rubber Research Scheme will show which is the best time to spray, and whether one spraying in a year gives satisfactory control.

As has been already indicated the cost of spraying must necessarily be high until a more satisfactory machine than any hitherto used is forthcoming. The cost of spraying 25 acres in the Matale district during March and April 1929 averaged about Rs. 11-00 per acre as follows:—

Sulfinette	...	Rs.	3-00
Labour	...	,,	6-00
Supervision	...	,,	1-00
Depreciation on equipment		,,	1-00
		Rs.	11-00

The sprayed field was favourably situated as far as water supply was concerned, and the figure of Rs. 11-00 per acre may be taken as near the minimum cost of spraying average mature rubber with any equipment available at the present time. Before such a costly measure can be recommended it will have to be shown not only that spraying provides an effective control of the disease, but also that sprayed areas give improved yields when compared with unsprayed areas.

Despite the many difficulties and disadvantages of spraying rubber it would be foolish to discard the method without extensive trial. *Oidium* may become so severe in Ceylon that an effective control measure is the only alternative to loss of the rubber, and an expenditure of Rs. 11-00 an acre would then become an insignificant item. Spraying is undoubtedly a practicable measure on an estate well supplied with water, and in the event of *Oidium* becoming a serious meance it might become an economic necessity.

9. *Dusting*.—Dusting or dry spraying as a combative measure against fungus diseases is a comparatively new development, and in some countries, notably the U.S.A., it is rapidly superseding wet spraying for the control of many diseases.

Dusts have been applied on a large scale in two ways, from an aeroplane and by projection from a dusting machine. The former is a very expensive method under the most favourable circumstances, and at the present time would be impracticable for the treatment of rubber in Ceylon. In order to dust mature rubber trees from a machine the latter must be sufficiently powerful to project dust to the top of the trees, and at the same time sufficiently light to be easily portable by coolies on the steep and rocky hillsides on which rubber in Ceylon is so commonly grown. Such a machine has been designed in Java and used with considerable success. The Rubber Research Scheme is at present in communication with manufacturers in three different countries with a view to securing a suitable apparatus for trial.

In the control of powdery mildews of other crops finely divided sulphur powder has almost universally proved to be the most effective fungicide, and reports from Java indicate that the *Oidium* of rubber is quickly killed by this dust. The sulphur is very easily and cheaply obtained in Java from local volcanoes, and it seems unlikely that it will be necessary to look beyond sulphur for an effective fungicidal dust against *Oidium*.

The application of a fungicide in the form of a dust, by obviating the necessity for water, overcomes one of the sources of expense in connection with spraying, and removes the limitation on a direct control of *Oidium* that a shortage of water imposes on many estates. Dusting is a far quicker operation than spraying: no climbing is necessary, and with the assistance of a light wind a considerable number of trees can be dusted from one position of the machine. A large acreage could thus be dusted with one apparatus during the time at which the operation is found to be most effective. Dusting should be far cheaper than spraying though no figures for dusting rubber are available at the present time. A serious limitation on the use of sulphur dust in certain districts in Ceylon would appear to be its tainting affect on tea grown in the vicinity, and it is difficult to see how a cloud of such a fine dust could be controlled so as to fall only on the rubber and not on the tea.

Rubber has been dusted against *Oidium* in Java from a power machine and by areoplane, and the results have encouraged the Dutch to believe that thev have found an effective means of controlling the disease. The method, however, is still in the experimental stage and it is not at present possible to say with any

degree of confidence that an infallible method has been found of dealing with the serious menace which *Oidium* threatens to become in Ceylon.

Conclusion.—It has been the writer's intention in this paper to present *Oidium* leaf disease of Hevea in a more serious light than that in which it is regarded by many rubber planters in Ceylon. The disease has only been known in the island for five years; yet in certain districts it is already a serious menace to the existence of the rubber. Whether the environmental conditions are such that the disease may also seriously threaten the health of the rubber in the chief low-country districts is not known.

That an effective means of controlling *Oidium* will eventually be discovered as the result of present researches is reasonably certain, but along whatever lines such combative measures fall the expense is not likely to be light, and it is possible that large sums of money may have to be spent to protect the rubber from the ravages of this disease.

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June 20th. 1929.

NOTICES.

SUBSCRIPTIONS.

Arrangements have now been made for Bulletins and Circulars of the Ceylon Rubber Research Scheme to be made available to non-contributors to the Scheme at the rate of Rs. 15-00 per annum, post free.

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